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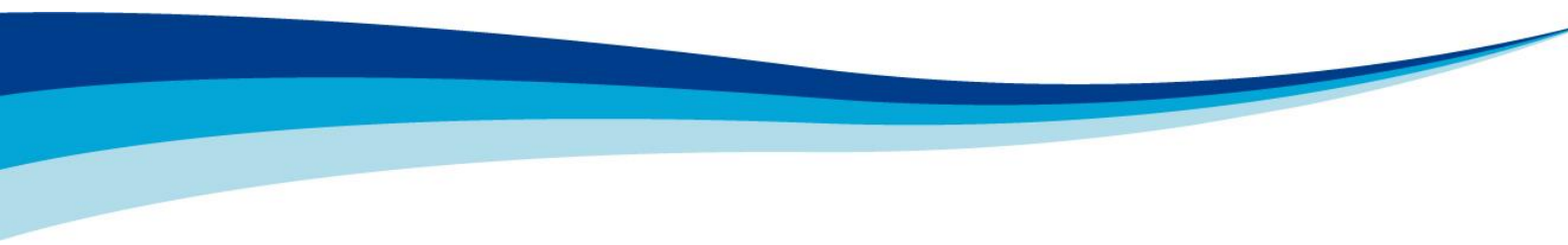
HOME MEDIA CENTER



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One of the most popular indoor entertainment systems nowadays is related to playing multimedia files, not only at home but also in public events such as watching movies in cinemas or playing music in nightclubs or pubs. Developers are responsible for making this easier and innovating in the development of these systems in different ways.

This project's goal was to develop a home media center which allows the user to play multimedia files easily. In addition, the development was intended to be structured aiming to create a system where modules can be easily added and, therefore, easy to update.

The user should be also able to deal with many different settings, such as managing users who will be allowed to use the system, wireless networks which can be used to connect the system, forecast, as well as advanced settings such as the IPs the system gives and shared folders.

As mentioned, this system should be able to browse over shared folders, as well as browse over USB external drives. In this way, the user in the same network has no need to go around with external devices from one device to another since he can create a shared folder to share all files across the network.

This project was successfully developed using incremental development strategies. Almost all planned functions were implemented to the system except for some features related to the Internet, such as the use of social networks and streaming of online content. This was intentionally left for further development in the future.

The significance of this thesis project lies in the fact that there are not so many home media centers available to download for free, so for those people who want to have a home media center, these home media center users will have another choice. Additionally, since the project is fully functioning and it will be released in the Internet for free, it can be downloaded by developers and inspire them to develop, add, and change some parts in order to improve the whole system.

KEYWORDS:

Home media center, multimedia player, home server.

CONTENT

FIGURES

TABLES

LIST OF ABBREVIATIONS (OR) SYMBOLS

DNS	Domain Name System.
DHCP	Dynamic Host Configuration Protocol.
GUI	Graphic User Interface.
HMC	Home Media Center.
RPi	Raspberry Pi.

1 INTRODUCTION

The term “domotics”, firstly used by journalist Bruno de Latour [1], comes from Latin domus (house) and Greek suffix –tica (art, science, study of). This term is also referred as home automation and its purpose is the automation of housework activities and to provide comfortable interaction between persons and house elements. Easy interaction is not only intended to ease normal people’s lives, but also to extend capabilities of disabled and old people.

Many different tasks may be accomplished, from controlling heating and lighting to home entertainment and audio-visual enjoyment. This last part will be the main topic and objective of this project, which aims to develop a Home Media Center (HMC from now on). The full meaning of a HMC may slightly vary depending on author’s focus since some of them only perform actions related to play music and/or video, and the most complex ones are capable to add security cameras for video surveillance and allow the user to browse the Internet.

Since 2007, when the first generation iPhone changed smartphone’s development direction, not only market started to grow up exponentially but additionally market forecast is still nowadays predicted to grow up, as we can see in the graph below.

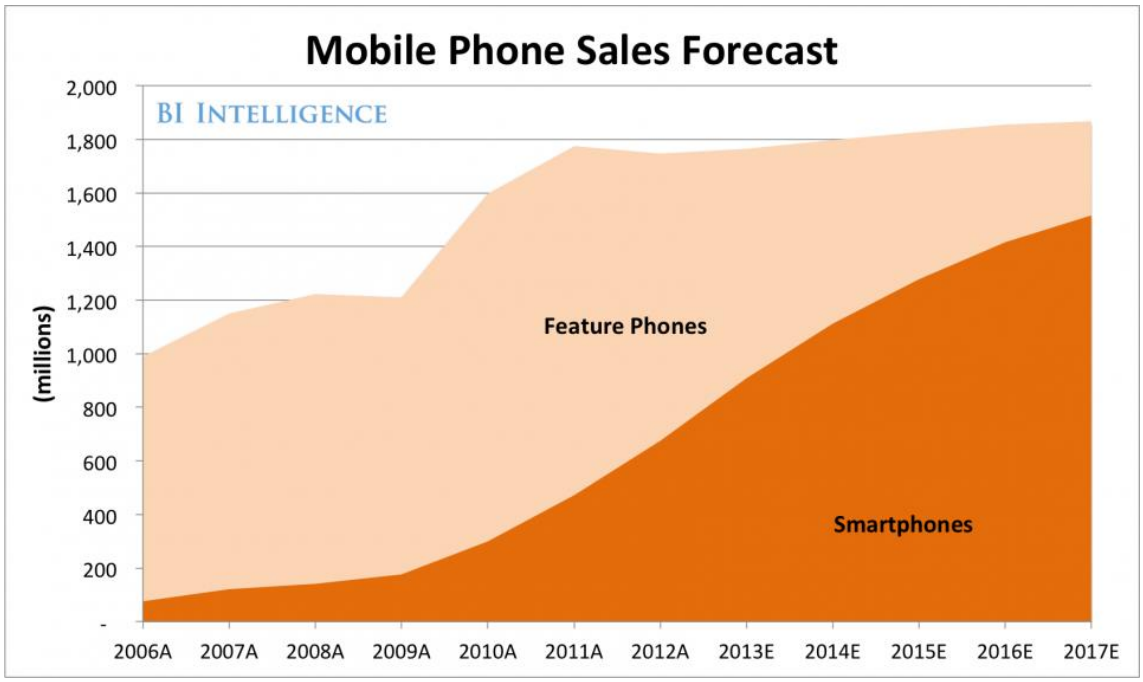

Figure 1: Mobile Phone Sales Forecast [2]

Smartphones and Tablets have a great reception among teens and young people. In the US for example, in 2011 the 36% of young adults (between 18 and 24 years old) had a smartphone, in 2012 raised up to 58% and in 2013 the 79% [3]. This is why nowadays smartphone companies have a challenge regarding market share penetration in terms of expanding their limits and including old people in their sales. Fortunately for them, they are achieving this and market share among old people is growing, although very slowly.

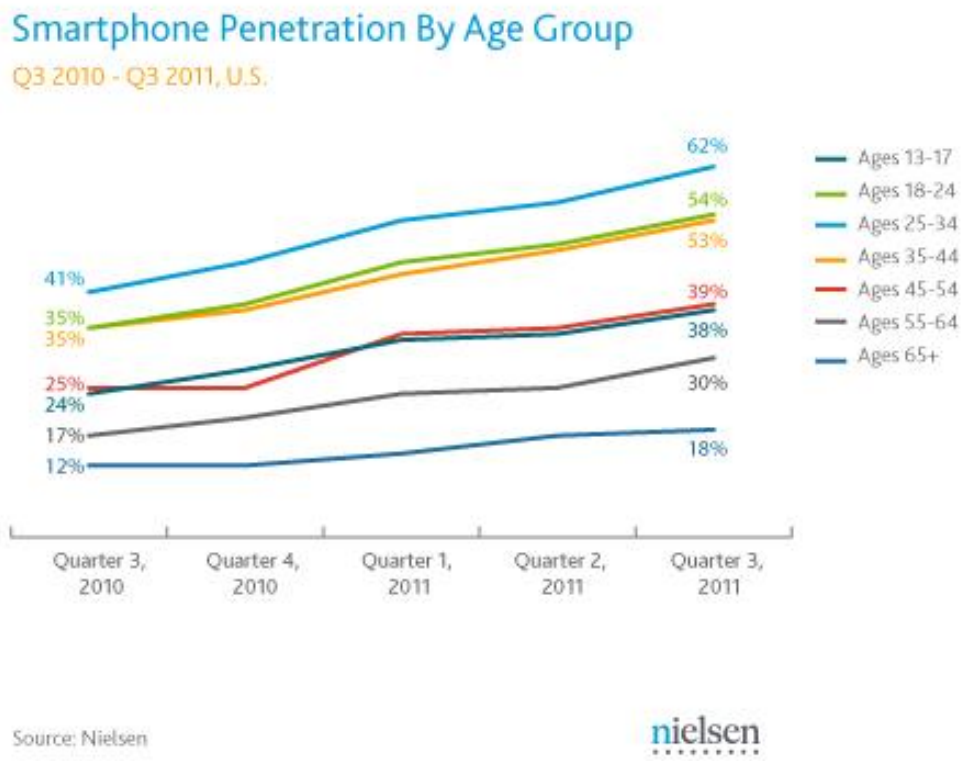

Figure 2: Smartphone penetration by age group [4]

In conclusion, smartphone sales and use is definitely growing in all aspects, and many people live hooked to their smartphones. When people want to watch the TV they tend to be closer to their phones rather than the remote, that's why enabling TV control over smartphones, is not a crazy idea. In addition, it is common to have at home more than one electronic device which is controllable by remote. This situation leads us to have several numbers of different remotes. For disabled and old people this situation is not only uncomfortable but might also create confusion, that's why if they are able to understand their smartphones which may adapt for their special needs, they will control easily any other device.

This project will consist on a system capable of playing different media files which can be controlled using other devices such as smartphones or tablets. The system will be ready to be used after turning the computer board on and no

additional configuration will be required. Thus, the user doesn’t have to worry and doesn’t need to be an expert.

In this paper, first of all, an introduction and description about the computer board will be presented since it’s the core of the project. Secondly, a theoretical approach for a good understanding in the system is described using a couple of important models (Finite State Machine and Flowchart). Next, key elements within the system will be explained in order to understand how each different part works and finally the conclusion will be written.

2 RASPBERRY PI

Raspberry Pi Foundation came up with the idea of a single, tiny and affordable computer board in 2006. Raspberry Pi is a small computer board which can be used in electronic projects and many of the things that a desktop PC does [5]. The reason why Raspberry Pi board is ready from the beginning to program is because their main goal is to extend computer knowledge among people, primarily among adolescents.

Depending on the capabilities someone needs, there are two different models, A and B. The model which was chosen for this project is B since it has higher capabilities and performance than A model. Here are some of the characteristics of B model.

- 2 USB ports.
- 1 HDMI port.
- 1 RJ45 port.
- RCA Video.
- Jack 3.5mm audio.
- Mini USB port.
- SD reader.
- 512MB RAM.
- GPIO input/output pins

As one of the goals of Raspberry Pi Foundation is teaching programming languages [5], RPi offers multiple choices when programming from the beginning and it’s not necessary to install any package if the programming language is C, Ada or Python.

RPi was firstly launched in 2012 [6] and from that moment until now, RPi community has been growing up. It's very important to mention that its official forum has over 50,000 different topics [7] and much other information can be found on the Internet, because when dealing with a fairly new product it's important to feel confident about it, and the more available information the better. Fancy ideas have been developed over RPi during this time, which help more people to have support on their own ideas.

3 SYSTEM

Currently developed HMC consists on a Raspberry Pi board computer (RPi from now on) which operates as a server, allowing all types of devices, from smartphones to regular computers, to connect to the RPi. At the precise moment when the RPi server turns on, if it doesn't find any suitable wireless network to connect, it will establish a WiFi hotspot automatically and when it's ready any device will be able to connect to the RPi via WiFi.

Naturally, it is necessary to connect the RPi to the output system in order to allow the user to play and to watch multimedia files. This output system might be a TV via RCA video cable or HDMI cable which also includes audio signals. Separated speakers may be connected to the RPi using its jack 3.5mm port. Below, it is possible to see a simple and easy to understand drawing about how the connections are organized.

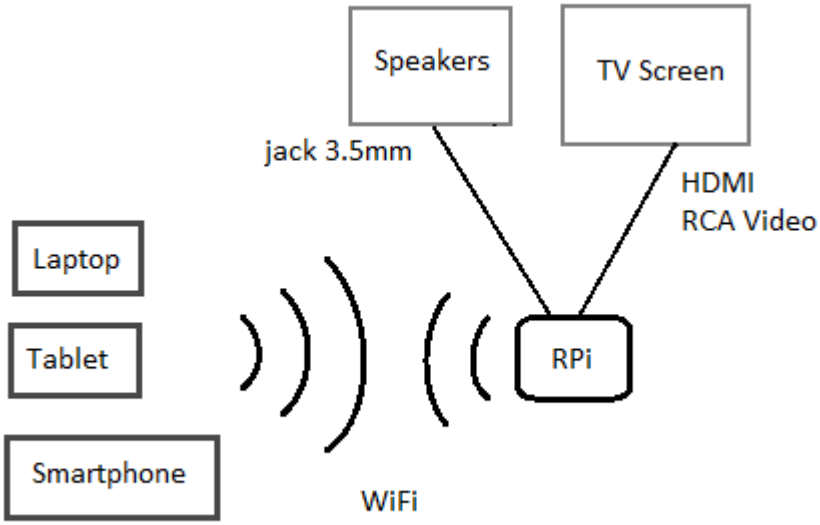

Figure 3: System Diagram

3.1 Finite State Machine

Finite state machine diagram is a model which may represent all different states or situations the machine may ever be. This means that it is possible to show this machine's memory because it is easily recognizable how it reaches one state from another. The term "finite" stands for the amount of all states it may be since we can count them. [8]

Despite this is not a complex system, a state machine diagram makes always the understanding easier for the reader and it shows clearly how it works and the different situations the system will encounter.

3.1.1 Waiting state

When the system is turned on it has to initialize some processes:

- Web server.
- IP configuration, DNS, IP tables initial configuration.
- Setting up the hotspot or connecting to the network.
- Python files which will be running all the time waiting for commands.

During this state the user can connect to the RPi via WiFi and he or she can command some requests such as changing settings, browsing folders which contain media files and playing those files. In order to connect to the RPi, the user has to open a web browser and go to the RPi IP address. When the user orders to play media file, next state will be triggered, “Playing” state.

3.1.2 Playing State

Playing state will be activated when a media file is wanted to be played and this state will be active as long as the media is being played. During this state, it won’t be possible to change any configuration or browse any folder because the user will be redirected to a “Remote” page where he or she can control the media through a remote interface.

There are two different ways to switch this state and going back to “Waiting” state. One way, similarly to the previous state transition, will be that the user may want to stop the media which is being played at that moment. The other way will be triggered when the media finishes to play all files that are intended to be played. In this case, when it's about music files, it may end up in a loop playing all the time the same playing list or same file endlessly. This actually depends on the system settings. However, regarding to video files or movies, after a movie finishes to be played, it will directly go to "Waiting" state.

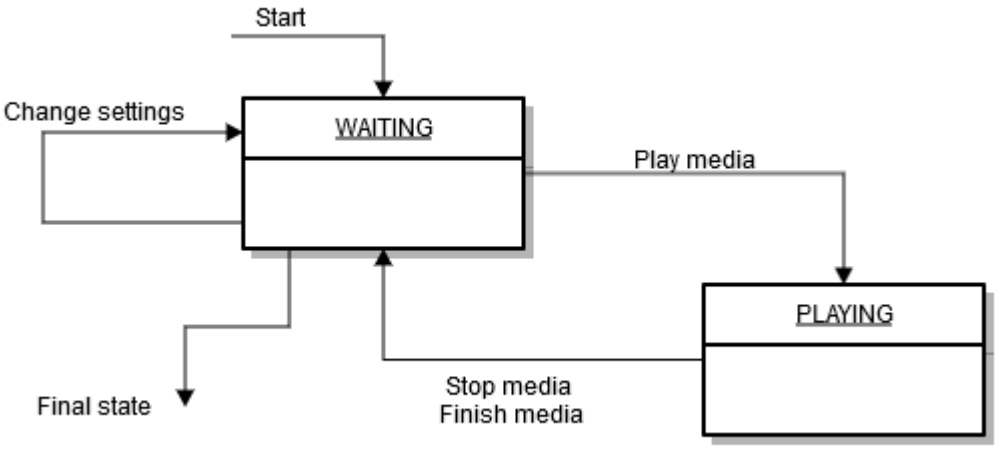

Figure 4: State Machine Diagram

3.2 Startup process Flowchart

Flowchart or flow diagram is a diagram that uses symbols to describe the steps in a process. It helps to better understand a problem or process, and each symbol has a special meaning [9]:

- Oval: It indicates starting and ending point of the process steps.
- Box: it represents an individual step in the process.
- Diamond: it shows a decision point (yes/no).

- Circle: It indicates that a step is connected to another page or part of the Flowchart.
- Triangle: it shows where an in-process measurement occurs.

A visual and written description about startup process will be described in order to explain in detail what the system does in the beginning. Flowchart picture is placed to **Appendix I** because of space limitations.

When the RPi starts, it will check whether it has stored networks and whether some of them are reachable. In this case, it will try all of them until it can connect. If it can connect, then it will request an IP to the DHCP server that it will most likely be the router. Otherwise, it will set up a new hotspot and establish its own preconfigured IPs.

After this, in both cases, shared folders might have been preconfigured in order to share files across the network. In this situation, it will try to mount them. Finally, at the end, it will start the web server.

4 KEY ELEMENTS

4.1 Media Player

Finding the appropriate media player is one of the most important parts in this process, since different media players have different features such as playable formats and commands. It's important to know about history regarding to video formats to understand current market and user needs.

Years ago, the use of Microsoft AVI format was widely extended because AVI container allowed different types of audio and video encoding [10]. A few years ago, MP4 format's rising changed statistics displacing Adobe FLV format. It became fairly famous because it allowed to play a highly extended video encode that even Blue ray players can reproduce [11]. Additionally, in Adobe Flash Player, several vulnerabilities have been found which may make the user mistrust the use of that format.

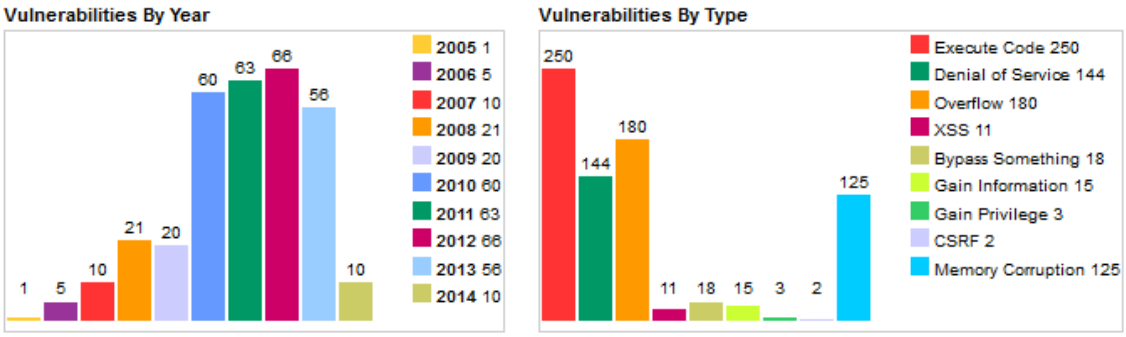

Figure 5: Adobe Flash Player vulnerability statistics [12]

Recently, MKV format file which is actually a container and not an encoding type changed again the statistics. As a container format, MKV allows the user to put not only audio and video which may be full HD but also subtitles, different audio tracks and dividing the movie by chapters. This makes MKV format one of the most flexible, if not the most flexible, video file format nowadays, because the user may disable or change different subtitles and audio tracks. It may include

additional metadata such as rating, description, cover art and more, and additionally, MKV format is an open standard video file which makes it easier for programmers to make video players [13].

In order to figure out which video player is the one which better fulfills our needs, a comparison table among the main video players for RPi has been made. Tested features are:

- Formats: Main formats they can read.
- Command: Whether it has a command line interface.
- H-A: Whether it uses hardware-acceleration to play videos.
- Rewind: Whether it has rewind option (back and forward).
- Stream: Whether it is possible to play streamed videos (RTSP).

Table 1: Comparison among video players

	Formats	Command	H-A	Rewind	Stream
OMXPlayer	MKV, MP4, AVI, WMV	Yes	Yes	Yes	Yes
VLC	MKV, MP4, AVI, WMV	No	Yes(*)	Yes	Yes
Mplayer	MKV, MP4, AVI, WMV	Yes	No	Yes	Yes
Gstreamer	MKV, MP4, AVI, WMV	No	No	No	Yes

(*): Theoretically it is possible, but it's not the official one and is not easy to enable hardware-acceleration.

OMXPlayer has been chosen to be the main media player in this project. OMXPlayer was developed by Edgar Hucek for XBMC project, specifically for the RPi and it's an open source program, so we can dive directly into the code, written mostly in C++ [14]. The most important features that were considered

crucial when deciding which media player might have been used for this project were the following:

- Support to hardware-accelerated video playback [15], which allows the RPi to play full HD video smoothly. Hardware acceleration allows using computer hardware in order to perform some functions intended to be faster such as Graphics Processing Unit (GPU).
- It allows reproducing online stream such as Youtube videos, live stream webcams and online TVs through Real Time Message Protocol (RTMP).
- As mentioned above, MKV containers may have different audio and subtitles tracks, and OMXPlayer allows the user via commands to switch them.

Despite OMXPlayer's code is free to use, there are some prebuilt binaries ready to download and use, making easy the usage of this media player. However, it was necessary to change some characteristics from the source code to make the program easier to use regarding the commands needed to rewind a video. By default, if the user wants to rewind he has to use arrow keys, making it difficult through commands because there are no ASCII equivalence for arrow keys. Therefore, a change in the source code was made and compiling process was necessary. This long time process may take from one to five hours since it needs to download huge files from the Internet. Fortunately, there are some scripts [16] which automate this process.

4.2 Web Server

A web server is a service intended to deliver web pages to clients who request them. The concept of client refers to someone who uses a compatible device to interact with the web server, such as web browsers. Since web servers are nowadays one of the backbones of the Internet, most of the sold devices can browse the Internet and use them. Using this widespread technology ensures us that our users will be able to use it. Actually, some services like security cameras transmit their information through a server which is available in the

Internet and therefore the owner can keep an eye on his/her house from everywhere. To sum up, we can say that the principle of using a web server to make a service available will ensure us compatibility among customers.

It's not common to connect several devices and interact with the HMC at the same time because the RPi is supposed to take control over a single TV screen. Hence, a powerful web server is not necessary and other features are highly considered as important such as how widespread it is, how easy to install it is, reliability, and support.

With its 512MB of RAM RPi is a low capabilities board PC, and for that reason is very important to decide which web server has a better performance. Apache and Nginx were chosen to test and compare them.

Apache HTTP server (Apache in short) was released in 1995 [17] and it quickly became very famous as we could see in the graph above. It's written in C language and nowadays it fully supports Perl, Python, Tcl and PHP.

Nginx is the most popular open source web server for high-traffic websites [18]. Some of the most popular websites which use Nginx are Instagram, Wordpress and NASA website.

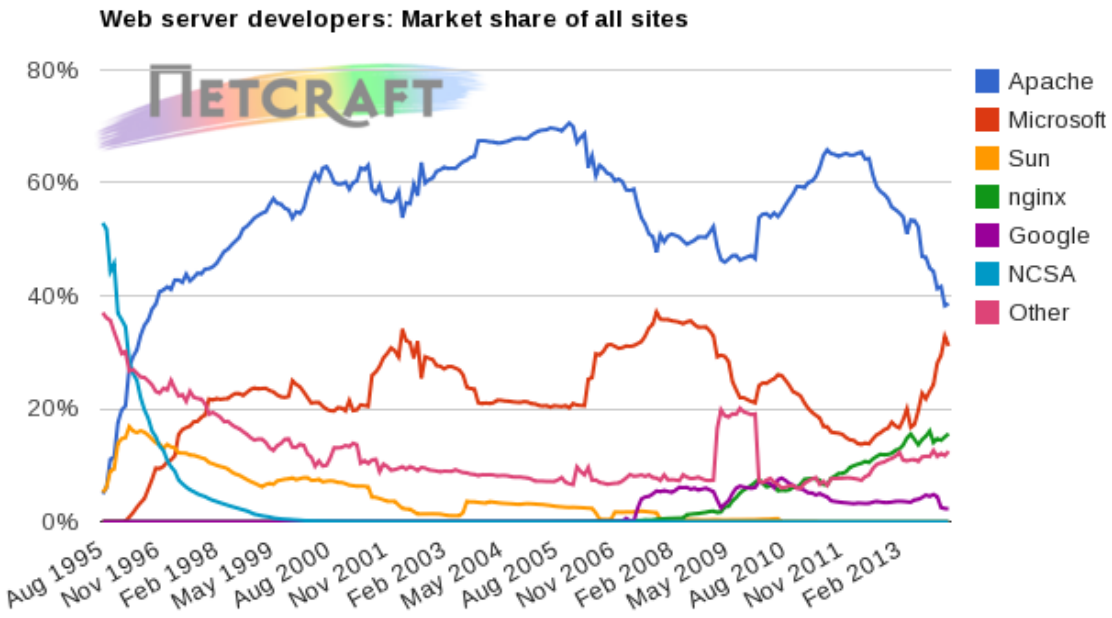

Figure 6: Web server market share [19]

In the next test, both Apache and Nginx web server have been compared using “ab” tool, an Apache benchmarking tool to measure performance in web servers [20].

Table 2: Testing static page

	Total Time	Connect (mean)	Connect (max)	Processing (mean)	Processing (max)	Waiting (mean)	Waiting (max)
Apache	12.118	158	7008	2701	11665	2552	11593
Nginx	5.296	64	331	1069	3052	1062	3052

This first table above shows the time (total time in seconds, rest in milliseconds) it takes when testing a static page. A state page is a pure HTML and non-dynamic web page.

Table 3: Testing dynamic page (loop)

	Total Time	Connect (mean)	Connect (max)	Processing (mean)	Processing (max)	Waiting (mean)	Waiting (max)
Apache	48.166	97	2294	11217	28360	7385	24269
Nginx	11.333	72	339	1616	8830	1730	8703

This second table above shows the time (total time in seconds, rest in milliseconds) it takes when testing a dynamic page. This dynamic page was a 10-times loop nested in a 200-times loop.

The command used for testing was the following, which sends 1000 requests and 250 concurrent.

ab –n 1000 –c 250 http://localhost

As we can see, Nginx performance fairly overcomes Apache performance. Thus, Nginx will be used.

Using a web interface, the user will be able to interact with the whole system. The web application makes possible to change some settings, to browse folders and to play files.

4.2.1 Web Application

Web application has been split up into 3 sections and it has been developed in a way that it's easy to add more modules in each section, taking care of scalability. In order to access this sections it may be possible to login or not (depends on the configuration). When some media file is being played, this webpage will redirect to the "Remote Page".

4.2.1.1 Home Section

Home section shows general information about weather forecast (5 days), current day, hour, etc… It is possible to add more features.

4.2.1.2 Settings Section

Settings section allows the user to modify RPi settings as well as performing some actions. It is possible to reboot or shutdown the RPi from this webpage. Here is where the user can add and delete the cities he/she wants to see in the forecast home section and the degree system (Celsius or Fahrenheit). Time zone can be changed in order to change RPi hour. Enabling or disabling login to access this page, and additionally it is possible to add and delete users. This new users won't be able to change some settings since this is based on permissions, therefore, only admin user will be able to change everything. Wireless configuration can be changed here, both for setting up a hotspot and to connect to other networks. Finally, we can also manage shared files.

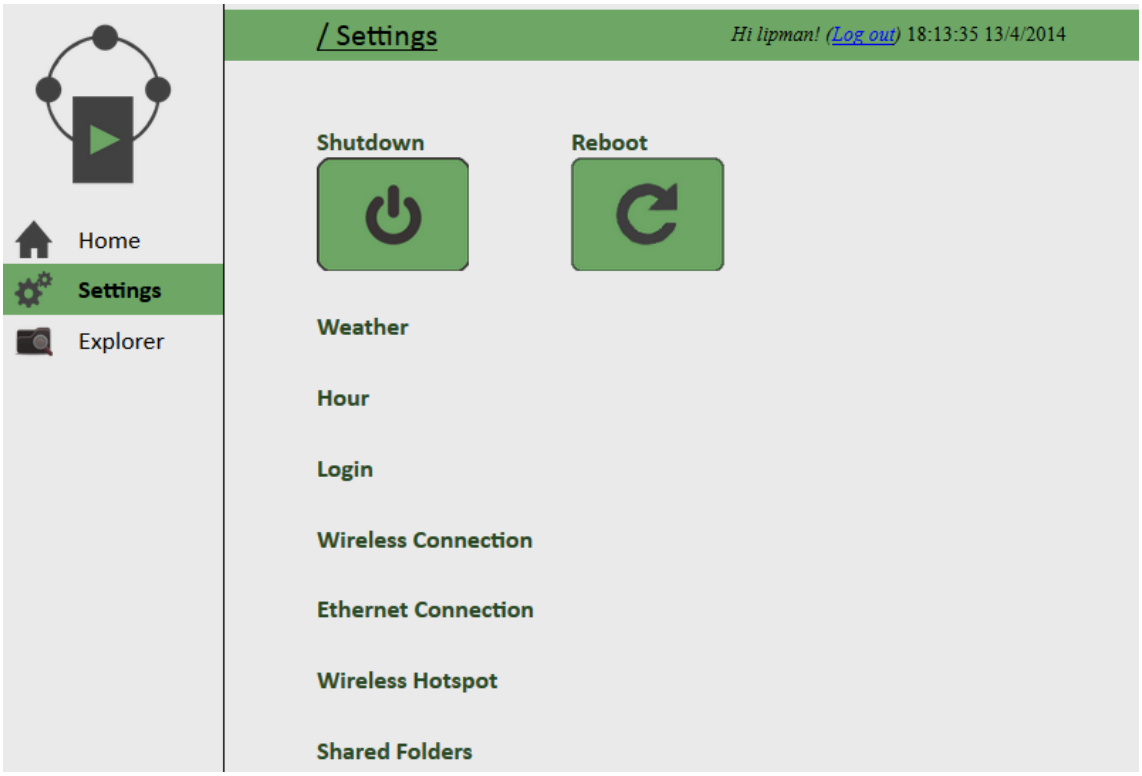

Figure 7: Settings

4.2.1.3 Explorer Section

Explorer section browse over user file system, external USB device connected to the RPi and shared folders. It will only be able to find files with allowed extensions (media extensions) such as mp3, avi, mkv, etc. After clicking in the file the user wants to play, it will be played and the user will be redirected to "Remote Page".

4.2.1.4 Remote Page

Remote Page displays a remote-like page which will allow the user to control the media player. Some of the features are play, pause, stop, next, previous, and volume control. This page will be displayed when some media file is being played, otherwise it won't be accessible. The user will be redirected to this remote directly when he starts to play something, and it will be the only page that can be displayed.

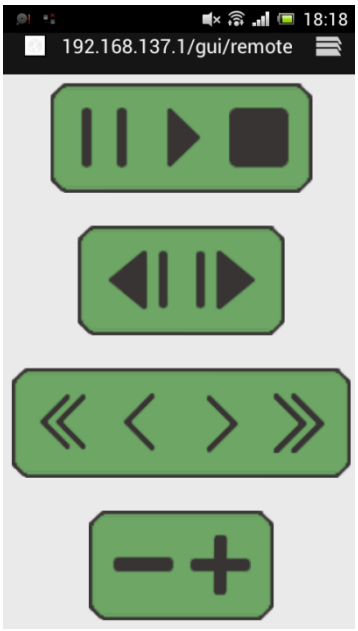

Figure 8: Remote

4.3 Wireless

The use of Internet has been growing exponentially since it was invented half a century ago. Hence, nowadays in the developed countries, Internet access is being provided at many homes. Taking account this widespread facility, the HMC may use an available wireless network to provide its services, or even making a hotspot and providing wireless Internet access by using its Ethernet port.

Wireless access is definitely a key element when using a HMC at home because it allows users to connect and control the whole system using any device with this WiFi feature.

According to both possibilities, when using a WiFi dongle on the RPi, in case there are no available WiFi networks (checked at startup), it is possible to make a new hotspot for devices to connect to the RPi. But in case there is an available network, the RPi may use it.

Range of wireless network, as well as quality and speed; depend mainly on the router the RPi is connected to and/or the dongle the RPi is using. This directly affects and determines the quality of those videos which are shared across the

network to be played remotely, because depending on bitrate of those videos, it might be possible to play them. Speed connection must be fast enough to stream smoothly all kind of videos.

4.3.1 Hotspot

After the system determines that no known networks are reachable, it will set up a hotspot automatically using hostapd, a user space daemon for access points and authentication servers developed by Jouni Malinen [21]. The hotspot will be set up using WPA2 technology since it's the safest one in the actuality and its name and its password can be modify in the settings page, wireless section.

When a device connects to the RPi, it will ask for an IP to dnsmasq, a DNS and DHCP server [22] which will provide corresponding IP addresses since a range of IPs may be written in the configuration file. This way, the only responsible of providing IPs will be this daemon. Here we can define IP ranges and amount of IPs by changing the network mask. 254 IPs are considered enough for a system which aims to be located at home.

In case we have Internet access through the Ethernet port, it will be necessary to enable packet forwarding using Iptables to allow the user to browse the Internet using the already created hotspot. This way, the user can use the network both for browsing the Internet and controlling the HMC.

All configuration details will be given in **Appendix II**

4.3.2 Wireless connection

If the RPi finds a suitable wireless network at startup, it will try to connect to it. This way, the user can reuse his/her own wireless network to take control over his TV.

The daemon which will be used to connect to the network will be wpa_supplicant, developed by Jouni Malinen [23]. In this case, the only necessary things that need to be configured are the network name and password.

All configuration details will be given in **Appendix III**

4.4 Sharing files

The idea of sharing files comes from the predictions about the average number of devices each home will have in the near future. Cisco estimated that by 2017 there will be 2.5 devices/connections per person in Earth and 5 devices/connections per Internet user [24]. When two or more devices are sharing the same network, they can also share files. Thus, it is easier and a better experience for the user to use this technology, avoiding the use of external hard drives or pen drives within the same house.

After connecting to the network, the RPi will look for configured shared folders and will make it available through the browser it has.

The higher the quality of the wireless dongle and router is, the larger files can be played through wireless. Four different video files have been tested in order to know an estimation of this capability.

Table 4: Comparison among video files

	Format	Resolution	Duration	Size	Video Bitrate	Playable
File 1	MP4	720x404	00:21:13	147MB	973 Kbit/s	Yes
File 2	MP4	1920x816	02:16:10	1.79GB	1893 Kbit/s	Yes
File 3	MKV	1920x1080	00:24:27	559MB	3201 Kbit/s	Yes
File 4	MKV	1920x1080	00:24:30	862MB	4923 Kbit/s	No

As we can see in the table above, the most important characteristic when determining whether a video can be played is video bitrate, which refers to the amount of bits per second needed to play a video file. This way, if our transfer data through the network is not high, it won't be possible to play high bitrate videos.

Samba is an open source suite that provides file sharing (among other possibilities) within a network [25]. It can operate using both SMB and CIFS sharing protocols in Linux as well as Windows. The use of this program gives the user an important advantage when configuring shared folders: no additional

program is needed because Windows is able to use this technology by default. Only mark the folder as shared and further configuration which is explained in **Appendix IV**.

5 CONCLUSION

Most of the currently available multimedia players present a wide lack of capabilities that we tried to achieve in this project. In terms of scalability they might not fulfill all users' expectations since free-to-download multimedia players are not easy to add new modules or functions from the developer's point of view, while expensive multimedia players available on the stores nowadays might become obsolete because formats and requirements can change and the user might fill up the hard disk.

In this project, new module addition is intended to be easy for the developer due to the structured way to develop the system, and obsolete technologies can be easily updated.

Not so many multimedia players use a shared folder mechanism to play files, which might certainly be very clever, since the user is most of the time controlling his own device and adding, deleting and downloading new media files directly to it.

During the development of this project most of the different parts have been programmed individually as separated modules. Therefore, it is theoretically easy to add more elements and new functionality. One of the most challenging things doing this project was developing the GUI, important part responsible for interaction between users and the program core. If we have a very powerful and complex system and the user is not able to interact with it properly, it would be considered as a failure.

More multimedia capabilities might be added and later implemented, such as the possibility of reading plain text files or showing a group of pictures in slides, giving control to the user to browse among them and go back and forward.

Regarding to music files, it will be possible to show more information about each song when and before playing such as author, duration, group, year, genre, etc. In case of Internet availability, a lyric search engine might be

implemented based on a third party API or external webpage, parsing the result and adapt it to the system.

We have to consider one of the multimedia player non-used capabilities, the online stream player, which may be used to stream online television channels or even security cameras. In this last case, we can also make use of the Internet (if available) and send information to some server or act like one, in order to allow outside of the local network users to connect to the system.

Finally, it’s important to make it easier for the user to upgrade different parts of the system individually. This might be done by regularly checking for updates or allowing and trusting the user to do it by himself or herself.

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APPENDIX I: STARTUP PROCESS FLOWCHART

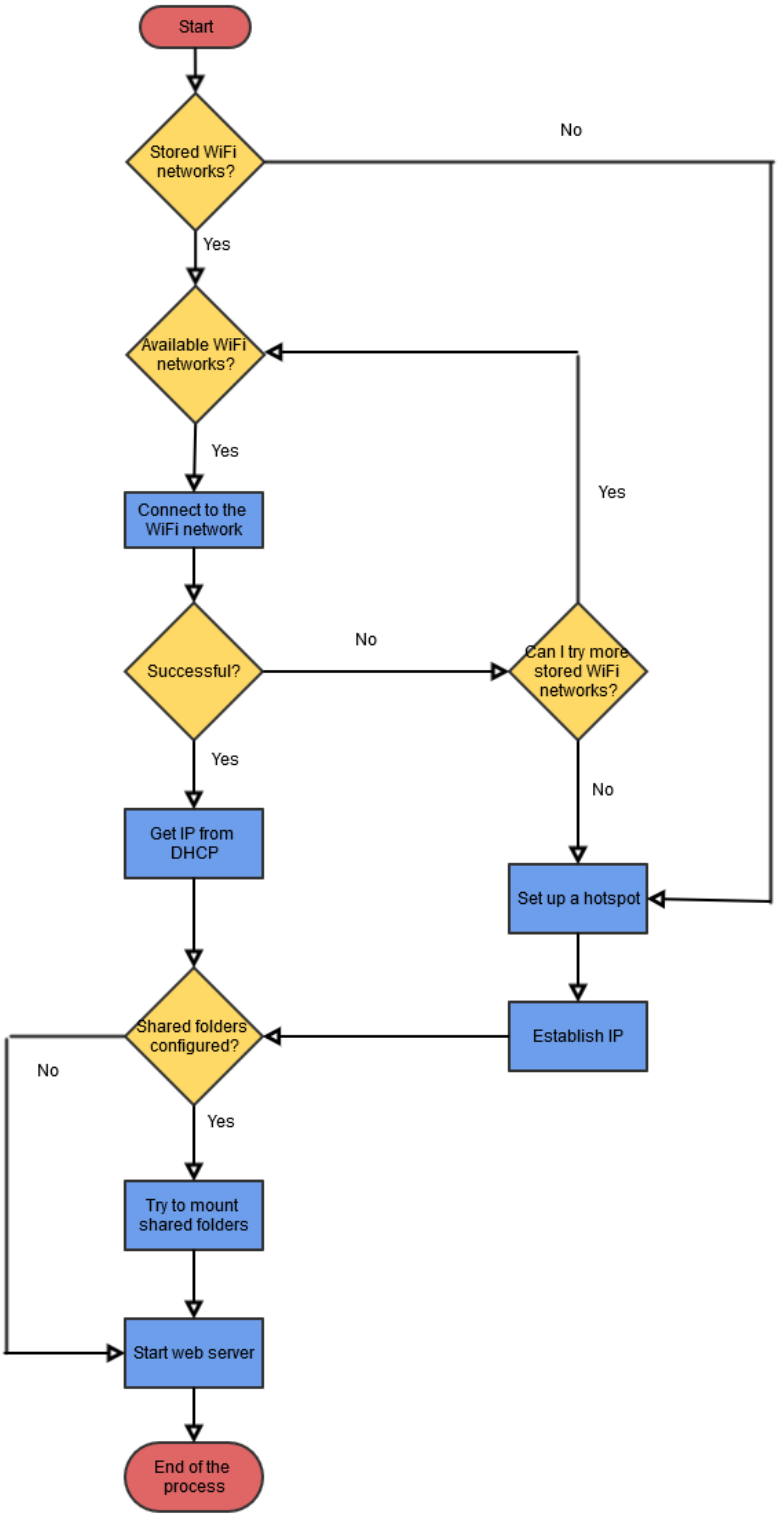

Figure 9: Startup Process Flowchart

APPENDIX II: HOTSPOT CONFIGURATION

/etc/dnsmasq.conf

```
no-resolv
interface=wlan0
dhcp-range=192.168.1.2,192.168.1.254,12h
server=8.8.8.8
server=8.8.4.4
```

/etc/default/hostapd

DAEMON_CONF="*/etc/hostapd/hostapd.conf*"

/etc/hostapd/hostapd.conf

```
interface=wlan0
driver=rtl871xdrv
ssid=name
channel=1
hw_mode=g
auth_algs=1
wpa=3
wpa_passphrase=password
wpa_key_mgmt=WPA-PSK
wpa_pairwise=TKIP CCMP
rsn_pairwise=CCMP
```

/etc/network/interfaces

```
auto lo
iface lo inet loopback

auto eth0
iface eth0 inet dhcp

auto wlan0
iface wlan0 inet static
   wireless-mode master
   address 192.168.1.1
   netmask 255.255.255.0
```

enabling NAT

```
iptables --flush
iptables --table nat --flush
iptables --delete-chain
iptables --table nat --delete-chain
iptables --table nat --append POSTROUTING --out-interface eth0 -j MASQUERADE
iptables --append FORWARD --in-interface wlan0 -j ACCEPT
```

APPENDIX III: WIRELESS CONFIGURATION

/etc/wpa_supplicant/wpa_supplicant.conf

```
network={
   ssid=”<NAME>”
   psk=”<PASSWORD>”
}
```

/etc/network/interfaces

```
auto lo
iface lo inet loopback

auto eth0
iface eth0 inet dhcp

auto wlan0
iface wlan0 inet dhcp
```

Connect to the hotspot

```
sudo wpa_supplicant –D wext –c pathconf –i wlan0
```

Restart networking service

```
sudo service networking restart
```

APPENDIX IV: SHARE FILES IN WINDOWS 8

Part 1: Mark the file as shared

Right click on the file we want to share, click on “Properties” and go to “Sharing” tab. Click on “Advanced Sharing…” and mark “Share this folder”.

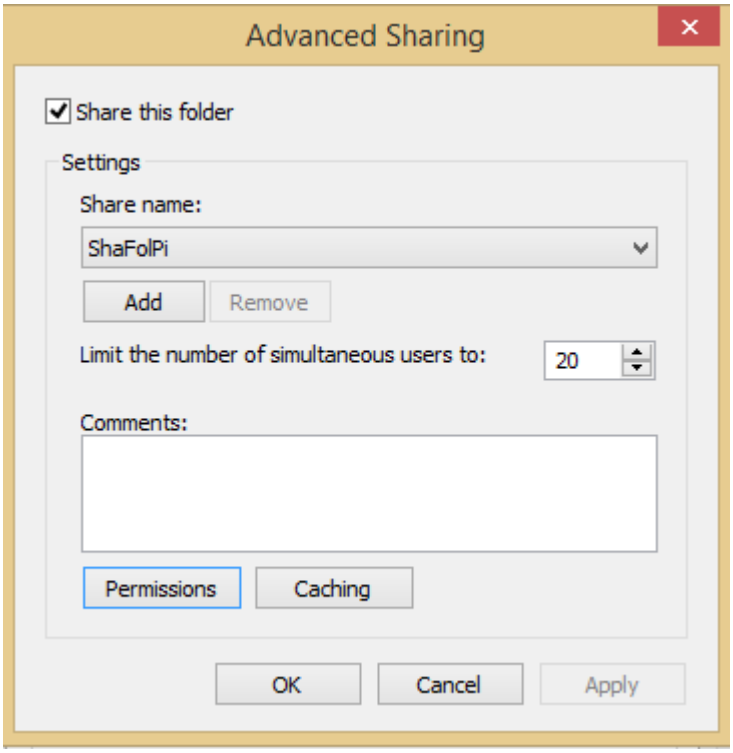

Figure 10: Advanced Sharing

Here we can edit the name that we’ll use later to share this folder. Finally, click on “Permissions” and enable “Read”.

Now, go to “Security” tab, click on “Edit” and click on “Add”.

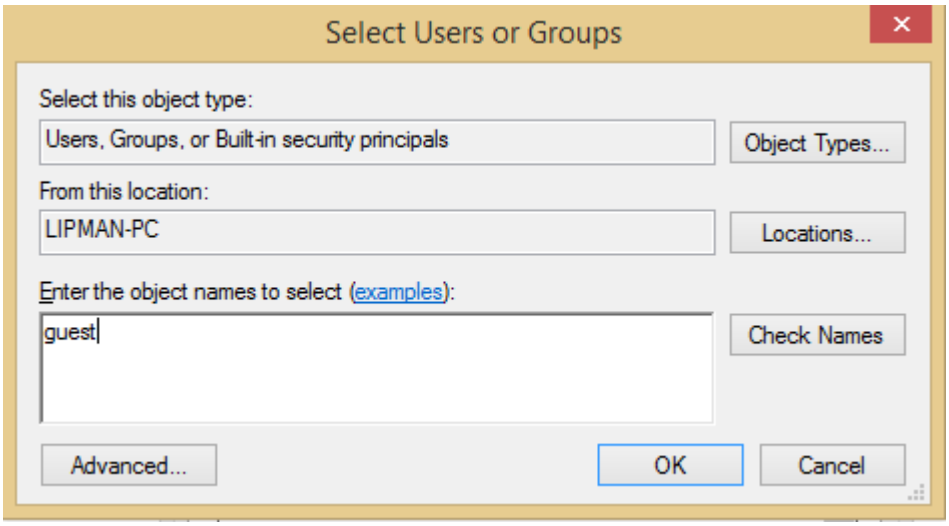

Figure 11: Advanced Security Permissions

Write in the textbox “guest”, because Guest user will be the one who will access to this file.

Part 2: Enable Guest user

Go to “Control Panel”, “User accounts” and click on “Manage another account”.

Figure 12: User Accounts

Finally, click on “Guest” user and turn it on.

Part 3: Disable password

Go to “Control Panel”, “Networking and Sharing Center” and click on “Change advanced sharing settings”. In “All networks” section, change from “on” to “off” the password protected sharing option.

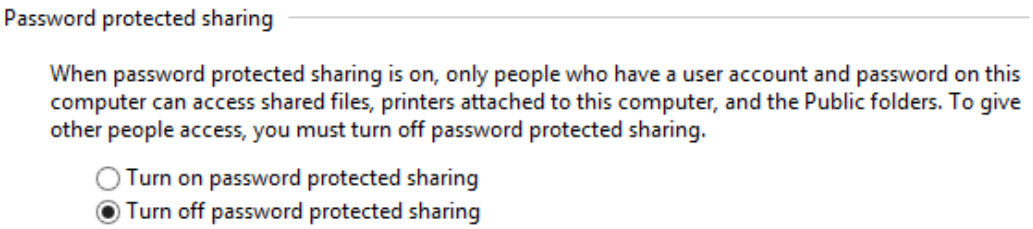

Figure 13: Password Protected Sharing